

## **Eddy current tools for education and innovation**

Gerhard MOOK, Jouri SIMONIN

Institute of Materials and Joining Technology, Otto-von-Guericke-University of Magdeburg,  
Magdeburg, Germany, Phone: +49 391 6714555, Fax: +49 391 6714569,  
e-mail: gerhard.mook@ovgu.de; jouri.simonin@ovgu.de; internet: <http://www.eddycation.de>

### **Abstract**

Teaching of theoretical and practical basics of eddy current inspection is difficult due to the missing clearness of the method. In x-ray and ultrasonic inspection personal experience of shade and echo eases the understanding for beginners. Eddy current phenomena mostly are unknown at all or they are limited to the eddy current brake.

The teacher has to explain a total new world and should ignite a certain enthusiasm from the initial amazement of his students. Despite the high scientific level of the few textbooks available for eddy current inspection they do not suite for this goal perfectly. Particularly with young students the interaction with their beloved toy - the computer - seems to be more promising. For this goal two tools have been developed being presented in this paper.

**Keywords:** Notebook driven eddy current instrument, education and training, absolute probe, differential probe, references.

### **1 The interactive textbook**

The effect of electrical, magnetic and geometric parameters on the eddy current signal is described in the normalized impedance plane (Foerster plot) independently from the probe. But it is not easy to understand the complicated hodographs and trajectories of the point movement mirroring the real and imaginary part of the impedance related to reactance of the “empty” probe. With a real eddy current instrument these trajectories cannot be demonstrated exactly. Neither the normalization nor the influence of the test frequency or the conductivity may be displayed directly.

To bridge this gap a semi-quantitative tool was developed by the students Verena von Hintzenstern, Tina Haase, Anne Goldammer und Sven Andres of the Otto-von-Guericke-University Magdeburg (Germany). It is able to visualize the most important effects avoiding time consuming and expensive numerical modelling algorithms. It forgoes exact field theory on behalf of speed and handling. The tool wants to be a textbook for playing.

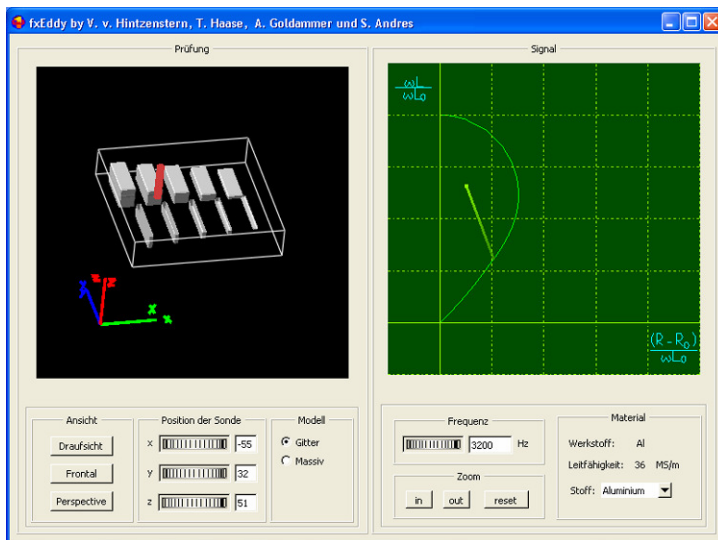


Figure 1a. Simulated inspection, left: Pick-up probe over non-ferromagnetic material; right: Lift-off signal in the normalized impedance plane

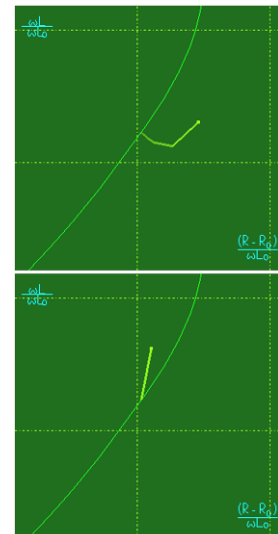


Figure 1b. Signals of reduced wall and surface crack

Figure 1a displays the set-up. On the left-hand side a symbolic probe may be moved over the surface by three position wheels. The reference piece contains slots (to simulate cracks) and local wall reductions from the back side. On the right-hand side a virtual eddy current instrument is shown displaying all signals in the normalized impedance plane. The user may zoom in to display details of the point movement. Additionally the frequency and the material under inspection may be selected. Figure 1b displays the impedance variation caused by wall reduction and surface cracks.

## 2 The tool box

When the student first time faces a real pick-up probe and a real eddy current instrument he is completely concentrated on the probe handling and will not be able to generate a regular signal on the screen. Common probes are too delicate in handling for beginners. To overcome this, a sliding probe shown in Figure 4 was designed. This probe additionally lets recognise its interesting inside.

The eddy current tool box includes a small USB-adapter with some hardware components and cables, one or more probes, different test pieces a manual and the software on a stick. This inexpensive set is available under the label EddyCation<sup>®</sup> (derived from eddy current und education).

Figure 2a and 2b bring up significant differences between an analogue instrument and the all-digital EddyCation system. In an analogue instrument the hardware generates the test signal, records the measurement and demodulates, filters, rotates, amplifies and displays it. These instruments perform very well but they are expensive.

The computers have developed so rapidly that today most functions may be accomplished by the software.

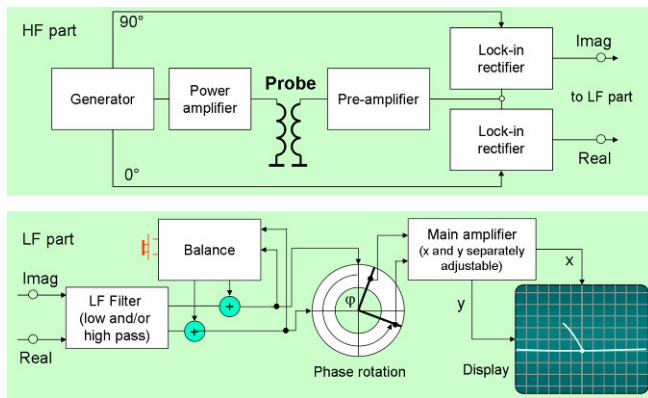


Figure 2a. Structure of an analogue eddy current instrument

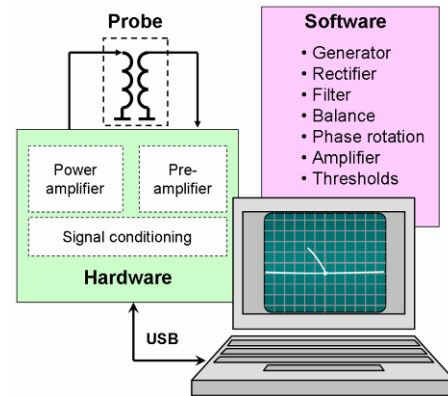


Figure 2b. Structure of the all-digital EddyCation instrument

Figure 3 shows the core of the EddyCation system: a USB-adaptor connected to a notebook running Windows<sup>®</sup> XP. The computer generates the exciter signal and processes the measured signal. The USB-adaptor contains components for signal conditioning and probe matching.

The instrument may be controlled by two selectable skins shown in Figure 4:

- Classic skin: separate track bars for frequency, gain, phase and filters,
- Compact skin: only one single track bar with selectable functions.

The main advantage of the EddyCation system is its connectivity to common notebooks used by most teachers and students. To practice eddy current inspection the adapter is plugged to a USB-port and the software is copied from a USB-stick. It does not need nor installation, nor boring passwords, nor permissions. So the student remains in his well known environment and may focus on signal recording and interpreting. Figure 3 shows the EddyCation system with an absolute probe over an aluminium strip with hidden defects.

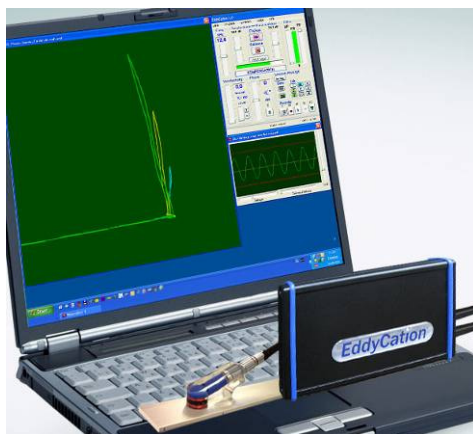


Figure 3. The EddyCation system

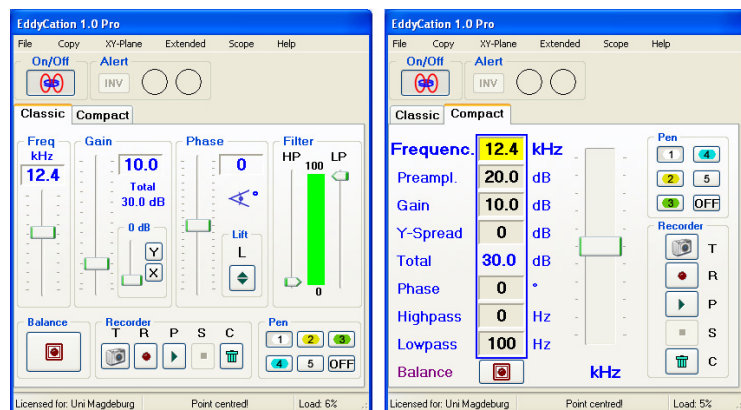


Figure 4. Classic and compact user interface

### 3 Practice makes perfect

Material sorting is a good introduction to get into the correlation between the normalized impedance plane and the indication of the instrument. For that, EddyCation comes with seven round blanks from materials of different conductivity and permeability (Figure 5). The hodograph of conductivity may be imagined by joining the end points of the lift-off trajectories. The large influence of the magnetic permeability also becomes obvious.

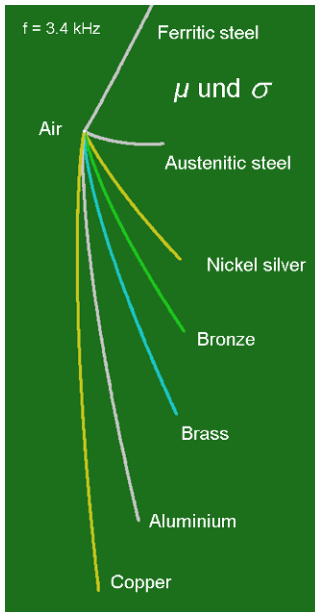


Figure 5. Sorting

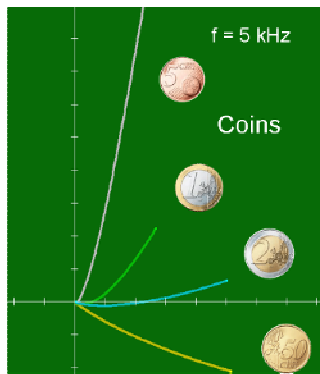


Figure 6. Coin rejection

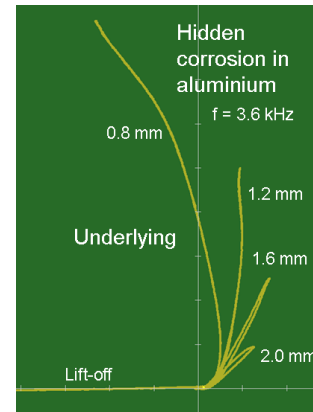


Figure 7. Detection of hidden corrosion in aluminium

The special sorting problem of coin rejection is investigated by the students most carefully (Figure 6). It can be shown that the Euro-coins are well selected combinations of materials of determined conductivity and permeability. With low effort these coins may be sorted contactlessly.

A further important topic is the detection of wall reductions caused by hidden corrosion for instance. A special aluminium piece simulates this defect by milled grooves. The students learn to interpret eddy current signals according to their phase shift. Figure 7 shows the phase shift with increasing underlying. This circumstance offers the opportunity to estimate the remaining wall. Valuable information about eddy current behaviour may be gathered with different inspection frequencies. EddyCation offers the opportunity to record the signal in different colours or to record only the track tip. This way, clear reports are generated being much helpful to prepare for the exam.

The wide topic of crack inspection is covered by a single reference piece. Slots of different depth have been eroded into an anodized aluminium sheet. This sheet may be inspected from both sides to simulate open and hidden cracks.

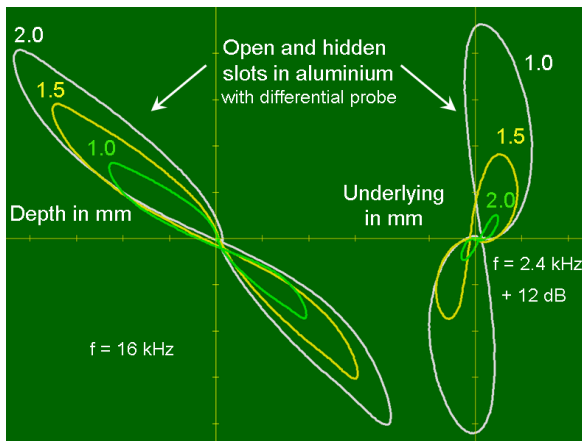


Figure 8. Differential probe signals of open and hidden slots in the linear XY-plane (combined from two pictures)

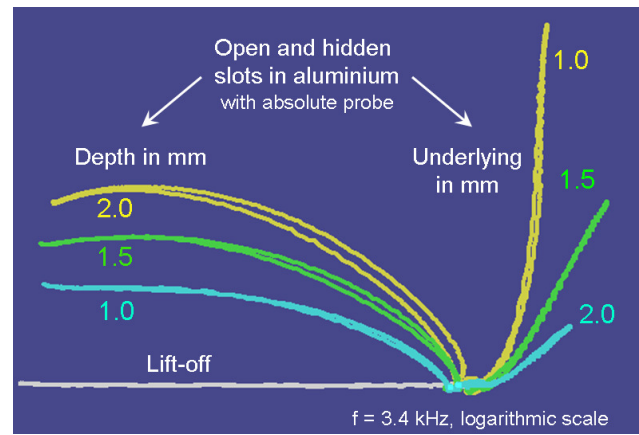


Figure 9. Absolute probe signals of open and hidden slots in the logarithmic XY-plane

The differential probe provides the signal pattern in Figure 8. The signal of the open slots increases significantly with increasing depth but only slightly turns clockwise. The amplitude of the hidden slots is much weaker (here -12 dB) but the phase behaviour is a suitable measure for the underlying of the slot.

Obviously open and hidden cracks produce very different signal amplitudes so that they cannot be displayed in one single XY-plane plot. Whether the gain is adjusted to surface cracks leaving the hidden crack signals too small or the gain is opened for hidden cracks overdriving the surface crack signals behind the XY-plane limits. EddyCation solves this problem by a logarithmic XY-plane option (blue background) able to display signals of widely varying amplitude (Figure 9).

#### 4 Time and thresholds

In addition to the XY-data representation EddyCation may use the Yt-mode. At two selectable velocities the point can be moved along the X-axis representing the time. This so called dynamic mode prepares the students for adjusting automatic production line systems. They learn to set the low and high pass filters correctly and understand the correlation with the inspection velocity.

The Y-component can be recorded and evaluated according to the signal magnitude using different thresholds. Among them are both simple X-Y-thresholds as shown in Figure 10 and more complex types like symmetric and circle thresholds.

#### 5 Automatic reporting

Many stand-alone instruments may be connected to a printer for reporting. Difficulties occur when the reports should be archived or transmitted to other sites. Here, EddyCation offers the opportunity to generate a MS-Office-Word<sup>®</sup> report automatically. Figure 11 shows an example.

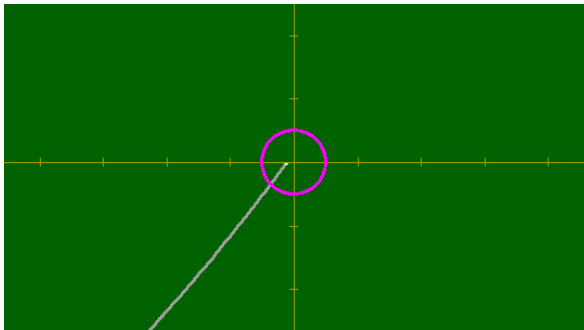
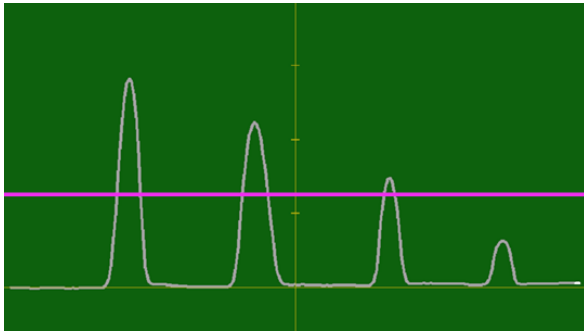


Figure 10. Above: Yt-Mode with threshold, below: XY-Mode with threshold for signal evaluation

EddyCation Report			
Item:			
Material:			
Task:			
Probe:			
Settings	Freq 1: white	Freq 2: yellow	Diff 1-2: green
Frequency:	15.4 kHz	5.0 kHz	
Total gain:	33.0 dB	36.8 dB	
- Driver level:	0.0 dB	0.0 dB	0.0 dB
- Pre-amplifier:	20.0 dB	20.0 dB	20.0 dB
- Amplifier:	13.0 dB	16.8 dB	-0.9 dB
Axes spread:	0 dB	0 dB	0 dB
Phase:	-3°	-30°	96°
Filter HP/LP:	0/100 Hz	0/100 Hz	0/100 Hz
			Remarks
Result			
Site	Date	Name	Signature

Figure 11. Automatically generated report

All settings and the XY-plane image are included. The student can concentrate on the essentials – the interpretation of the eddy current signals. Directly in MS-Office-Word® he can add comments and conclusions. The report can be printed like any other document. Additionally, the reports can be gathered, compared, archived or transmitted via network. Anyhow, the report remains on the hard disc of the student’s notebook and he can prepare properly for the exam.

## 6 For advancers

Having passed the basic course of eddy current inspection the students wait for more challenging tasks. No doubt, multi-frequency eddy current inspection is one of them. EddyCation may feed the probe with two frequencies simultaneously and may display two points in the XY-plane. Both frequency channels are set independently. An additional channel displays the difference of these channels as a third point. This technique allows suppressing of disturbances on the measurement.

## 7 Résumé

FxEddy and EddyCation ([www.eddycation.de](http://www.eddycation.de)) are PC-based tools making eddy current teaching and learning easier. The teacher clearly may demonstrate facts and methods via notebook and data projector. The student keeps motivation and concentration over long terms due to the interactivity and diversity of the work. Eddy current inspection becomes playing easy to learn.